Atmospheric and Space Electricity

AE11A MC: Hall D Monday 0830h

Lightning and Storm Electrification I

Presiding: **D Rust,** NOAA/National Severe Storms Laboratory**; J Dye,** NCAR/MMM

AE11A-0054 0830h POSTER

Joint Observations of Marine Lightning Over the Atlantic by the FORTE Satellite and the United Kingdom Meteorological Office sferics array

Abram R Jacobson[1] ((505)667-9656; ajacobson@lanl.gov)

Earle Williams[2]

[1]Space and Atmospheric Sciences Group, Los Alamos National Laboratory, Mail Stop D466 LANL, Los Alamos, NM 87545

[2]Massachusetts Institute of Technology, MIT 48-24, Cambridge, MA 02139

During 1998 and 1999, the FORTE satellite conducted occasional observations of radio-frequency emissions from lightning over the Atlantic Ocean. At the same time, the Atlantic was reasonably well covered by a sferics-receiver array operated by the United Kingdom Meteorological Office. Comparison of the two systems signals indicates that subsets of each dataset represent correlated observations of the same strokes. The storms successfully seen in common by the two systems are primarily over the ocean, with relatively few strokes over land. Because "groundtruthing" of lightning over the oceans is in only a primitive stage, we will present the characteristics of the strokes and flashes observed in common by these two systems, and in particular the differences from our prior experience with RF/sferic correlations between FORTE and NLDN.

AE11A-0055 0830h POSTER

A Clustering Algorithm for the Automated Storm Identification of Space-Based Optical Lightning Data

Angela M Mielke[1] (505-667-2784; amielke@lanl.gov)

Sean M Davis[2] (505-667-8784; sdavis@lanl.gov)

Abram R Jacobson[2] (505-667-9656; ajacobson@lanl.gov)

David M Suszcynsky[2] (505-665-3119; dsuszcynsky@lanl.gov)

[1]NIS-7: Safegaurd Systems Los Alamos National Laboratory, MS E541, Los Alamos, NM 87545, United States

[2]NIS-1: Space and Atmospheric Sciences Group Los Alamos National Laboratory , MS D466, Los Alamos, NM 87545, United States

The Fast On-Orbit Recording of Transient Events (FORTE) satellite is a joint Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL) experiment that was launched into a nearly circular low-earth orbit on August 29, 1997. The payload consists of broadband Very High Frequency (VHF) receivers and a two-sensor Optical Lightning System (OLS). One of the OLS sensors, the Lightning Location System (LLS), is a narrow band (777.6 nm + 0.5 nm) 128 x 128 pixel charge coupled device (CCD) array that is autonomously triggered, and provides imaging and geolocation of lightning events to within a pixel size of 10 km x 10 km.

This paper presents a data-clustering algorithm which uses FORTE LLS event locations to both (a.) discriminate between lightning and energetic-particle/glint events and (b.) identify regions of high event density that are associated with storm activity. In addition to the utilization of basic statistical and data-clustering techniques, data driven thresholds are employed in the identification of probable storm regions.

The application of automatic data discovery and analysis techniques allows for an efficient, flash/storm-level analysis of the more than 30 million events recorded by FORTE LLS, including a statistical characterization of seasonal, diurnal, and geographical variations in lightning and storm activity.

AE11A-0056 0830h POSTER

Coincident Observations of Lightning by the FORTE Photodiode Detector and the New Mexico Tech Lightning Mapping Array During STEPS 2000

Cynthia Machacek Noble[1] (405-325-6561; cmachac@rossby.metr.ou.edu)

William H. Beasley[1]

Tracy E. Light[2]

David M. Suszcynsky[2]

Timothy Hamlin[3]

[1]School of Meteorology, University of Oklahoma, 100 East Boyd St., Room 1310, Norman, OK 73019-1013, United States

[2]Los Alamos National Laboratory, Space Atmospheric Sciences, NIS-1, MS D466, Los Alamos, NM 87545, United States

[3]Geophysical Research Center, New Mexico Institute of Mining and Technology, Socorro, NM 87801, United States

During the STEPS 2000 experiment, the Fast On-Orbit Recording of Transient Events (FORTE) satellite passed over a thunderstorm which was also within view of New Mexico Tech's 3-D Lightning Mapping Array (LMA). The FORTE pass occurred on June 25, 2000 from approximately 7:52:00 UTC to 7:54:40 UTC. During that time, the PhotoDiode Detector (PDD) aboard FORTE triggered for approximately 60 events classified as lightning and the LMA mapped approximately 200 lightning flashes. This paper investigates the relationship between the physical characteristics of the lightning channels, as mapped by the LMA, and whether those flashes were also detected by the PDD. Maximum height reached by the lightning discharge, horizontal dimensions of the discharge, flash complexity, and the length of time for the extended flash are examined.

AE11A-0057 0830h POSTER

FORTE Observations of Simultaneous VHF and Optical Emissions From Lightning: Optical Source Properties and Discrimination Capability

Sean M Davis[1] (505-667-8784; sdavis@lanl.gov)

David M Suszcynsky[1] (505-665-3119; dsuszcynsky@lanl.gov)

Matthew J Heavner[1] (505-665-4619; heavner@lanl.gov)

Abram M Jacobson[1] (505-667-9656; ajacobson@lanl.gov)

Tracy E Light[1] (505-667-5567; tlavezzi@lanl.gov)

[1]NIS-1: Space and Atmospheric Sciences Group Los Alamos National Laboratory, MS D466, Los Alamos, NM 87545, United States

The Fast On-Orbit Recording of Transient Events (FORTE) satellite is a joint Los Alamos National Laboratory and Sandia National Laboratories experiment that was launched into a nearly circular low-earth orbit on Aug. 29, 1997. The payload consists of broadband VHF receivers and a two-sensor Optical Lightning System (OLS). The OLS is comprised of a broadband (400 - 1100 nm) silicon photodiode detector (PDD) that collects 1.92 ms records of lightning transients with a 15 us time resolution, and a narrow-band (777.6 nm 0.5nm) 128 x 128 pixel CCD array called the Lightning Location System (LLS) that provides imaging and geolocation of these events to within a pixel size of 10 km x 10 km.

This paper presents an overview of the phenomenology of the optical component of temporally-coincident FORTE VHF / FORTE PDD events. In this study, FORTE VHF data provides lightning type information. We discuss the broad correlation between lightning type, effective optical pulse width, and peak optical power. We find that in general, negative cloud-to-ground lightning produces higher peak powers and lower pulse widths at the detector, and that in-cloud lightning typically has lower peak powers spanning a broader range of pulse widths. In addition, a low-end cutoff of effective pulse widths near 150 microseconds has been observed. The role that lightning source height, scattering, and temporal source duration play in this cutoff is discussed.

AE11A-0058 0830h POSTER

Comparisons of Satellite Optical Observations with Ground-Based Observations of Lightning, Then and Now

William H. Beasley[1] (405-325-3440; wbeasley@ou.edu)

Cynthia M. M. Noble[1] (405-325-6561; cnoble@ou.edu)

Bruce C. Edgar[3]

David M. Suszcynsky[2]

Tess E. Light[2]

[1]School of Meteorology, University of Oklahoma, Norman, OK 73019, United States

[2]NIS-1, Los Alamos National Laboratory, Los Alamos, NM, United States

[3]None, Hinsdale Ave., Torrance, CA, United States

About 20 years ago, the first and third authors presented a paper comparing the optical observations of lightning from the DMSP Piggy Back Experiment (PBE) with ground-based manually determined lightning ground-strike locations. In one case in 1977 there were eleven optical events from one satellite pass over the region of interest for which there were ground-based data available. In general there were few periods of overlap because the area covered by the ground-based research direction-finding systems was limited. Now, the Photo-Diode Detector (PDD) on board the FORTE satellite, a cooperative effort between LANL and Sandia Labs, provides hundreds of optical observations that are correlated with ground-strike location data from the National Lightning Detection Network on every pass over a stormy region of the U.S. Though in some ways it should not be too surprising that there are similarities, since the PDD instrument on the FORTE satellite is very similar to the PBE instrument, it has been very interesting to re-visit the 1977 observations to compare what was seen and what was not seen by the satellite and ground-based systems, then and now. The characteristics of the optical observations for which there were no ground-strike data in 1977 are remarkably similar to those of the events attributed to cloud flashes in the FORTE data sets. We show the power-time histories of the optical observations then and now.

AE11A-0059 0830h POSTER

North American Lightning Detection Network (NALDN) - First Results: 1998-2000

Richard E. Orville[1] (979-845-9244; rorville@tamu.edu)

Gary R. Huffines[2]

William R. Burrows[3]

Ronald L. Holle[4]

Kenneth L. Cummins[4]

[1]Dept. of Atmospheric Sciences, Texas AM University, College Station, TX 77843-3150, United States

[2]Air Force Institute of Technology, Wright Patterson Air Force Base, OH

[3]Meteorological Research Branch, Meteorological Service of Canada, Downsview, Canada, Canada

[4]Global Atmospherics, Inc., Tucson, Arizona

Cloud-to-ground lightning data have been analyzed for the years 1998-2000 for North America (Canada plus the contiguous United States) for all ground flashes, positive flashes, the percentage of positive lightning, peak currents for negative and positive lightning, and for negative and positive multiplicity. The authors examined a total of 88.4 million flashes divided among the three years, 30.6 million (1998), 29.6 million (1999), and 28.3 million (2000). The highest flash densities, uncorrected for flash detection efficiency, occur in the provinces of Alberta and Saskatchewan (1-3 flashes km-2) in Canada, and along the Gulf Coast and in Florida (exceeding 9 flashes km-2) in the United States. Maximum positive flash densities in Canada range from 0.1 to 0.3 flashes km-2 and in the United States, to over 0.7 flashes km-2 (areas in the Midwest, the Gulf Coast, and Florida).

AE11A-0060 0830h POSTER

Twelve Years of Cloud-to-Ground Lightning Characteristics, 1989-2000: Small Scale Results

Brandon L Ely[1] (1-979-458-0555; bely@tamu.edu)

Scott M Steiger[1] (ssteiger@ariel.met.tamu.edu)

Stephen E Phillips[1] (sphill@ariel.met.tamu.edu)

Richard E Orville[1] (rorville@tamu.edu)

Gary R Huffines[2] (Gary.Huffines@afit.edu)

[1]Texas A&M University Dept. of Atmospheric Sciences, 1204 Eller O&M Building, College Station, TX 77843-3150, United States

[2]Air Force Institute of Technology, Wright Patterson Air Force Base, OH 45433, United States

The National Lightning Detection Network recorded over 250 million cloud-to-ground lightning flashes from 1989 to 2000. Analysis of lightning flash density and polarity reveal significant small-scale geographical variations. These variations can occur as broad trends over several hundred kilometers, or as sharp contrasts over as little as a few kilometers. This study focuses on four regions of the United States: the Pacific Coast, Rocky Mountains, Appalachian Mountains, and the Houston Metropolitan area.

In the Pacific Coastal region, an interesting geographical variation is found in the percentage of positive lightning. A higher than normal percentage of positive lightning discharges (up to five times the national average) dominates the coastline, but drastically decreases about a hundred kilometers inland. In the Rocky and Appalachian Mountains, observations of lightning flash density reveal two distinct and opposite patterns, despite similar terrain. Although located at about the same latitude, the southern Rockies display a significant increase in flash density over regions of high terrain, while the southern Appalachians show a significant decrease in flash density as elevations increase. Further analysis shows that the pattern in the Southern Rockies is a result of a large number of days with low flash counts, while the pattern in the Appalachians results from a few large events. The top 5 percent of lightning producing days accounted for 28.6 percent of all flashes in the high terrain of Rockies, but 56.9 percent of the total flashes in the Appalachians. Our final area of research concerns the lightning enhancement over the Houston, TX region. Fine scale analysis of this area suggests two leading hypotheses to explain this phenomenon. The first explanation is that the complex coastline of Galveston Bay in combination with the urban heat island alters the wind flow in the Houston area, initiating new thunderstorms directly over the city. The second possibility is that pollutants from an industrial city like Houston can act to increase the electrical charge separation processes within storms.

The culmination of these three studies will lead to a better understanding of lightning, one of nature's most incredible displays of power.

AE11A-0061 0830h POSTER

Climatological Studies of Severe Thunderstorm CG Lightning Polarity and Near-Surface Equivalent Potential Temperatures

Walter A. Petersen[1] (970-491-8516; walt@radarmet.atmos.colostate.edu)

Lawrence D. Carey[2] (970-491-8219; carey@cira.colostate.edu)

Steven A. Rutledge[1] (970-491-8283; rutledge@radarmet.atmos.colostate.edu)

[1]Colorado State University, Department of Atmospheric Science 205b ATS, Ft. Collins, CO 80523-1371, United States

[2]North Carolina State University, Department of Marine, Earth and Atmospheric Science, Raleigh, NC 27695-8208, United States

A recent conceptual model (Smith et al., 2000) relates the cloud-to-ground (CG) lightning polarity of tornadic thunderstorms to the relative movement of the storm systems through ridges of near-surface equivalent potential temperature (theta-e; a measure of atmospheric instability to moist convection). In order to test/extend this conceptual model on/to climatological temporal and spatial scales, we have examined spatial-temporal distributions of both predominately positive CG (PPCG, > 50%) and predominately negative CG (PNCG; > 90%) severe storm events observed over 10 warm seasons (Apr.- Sept., 1989-98) as they relate to concomitant distributions of near-surface theta-e (computed from NCEP Reanalysis data on a 2.5 x 2.5 Degree grid). In order to clearly isolate correlations between theta-e and the spatial distributions of severe storm CG polarity, only event days with high flash density PPCG and PNCG events were included in the analysis.

Our analysis suggests that peaks in PPCG dominated severe thunderstorm frequencies generally occur upstream (west and northwest) of theta-e ridges, either in the gradient region along what may be a dryline signature in theta-e, or along the top of theta-e ridges in regions that are likely still under the influence of polar fronts during Northern Hemisphere summer. Conversely, peaks in negative CG-producing severe storms are located to the southeast of the +CG maxima, closer to the theta-e ridge axis in higher mean values of theta-e. This result is broadly consistent with the conceptual model developed by Smith et al. (2000). Importantly, the spatial correlation between theta-e and PPCG/PNCG severe storm events is still noisy, suggesting that other parameters (in addition to theta-e) are also influencing the location and frequency of severe PPCG storms.

AE11A-0062 0830h POSTER

Cloud-to-Ground Lightning Characteristics Over Houston, TX: 1989-2000

Scott M Steiger[1] (1-979-458-0555; ssteiger@ariel.met.tamu.edu)

Richard E Orville[1] (1-979-845-9244; rorville@tamu.edu)

[1]Texas A&M University Dept. of Atmospheric Sciences , 1204 Eller O&M Building, College Station, TX 77843-3150, United States

Cloud-to-Ground (CG) lightning detected by the National Lightning Detection Network (NLDN) indicates a relatively high flash density over Houston, Texas for the twelve-year period 1989-2000. A significant enhancement of 45% in the flash density is observed compared to the nearby surrounding areas. The strength of the enhancement varies based on season and time-of-day, with the greatest increases occurring during the summer (58%), and during the 0900-1800 LST time periods in each season. Observations indicate that large lightning events (defined as days with > 1,000 flashes in a geographic region that includes Houston and nearby rural areas) were responsible for the climatological lightning anomaly, and that increased thunderstorm initiation was not the most significant cause of the enhancement. A decrease (-12%) in the percentage of positive flashes is observed over the city. Higher negative median peak currents along the coast and well into the Gulf of Mexico were also discovered. Several explanations for our observations are suggested. The urban heat island and increased cloud condensation nuclei (CCN) concentrations, especially from industrial pollution, are shown to be significant factors in creating lightning enhancement. Pollution effects are speculated to cause a change in a thunderstorms charge distribution, which can affect the polarity of CG flashes. The potential effect of the nearby coastal Gulf salt water on the measured peak current is examined.

AE11A-0063 0830h POSTER

Cloud-to-Ground Lightning and Precipitation During the Great Flood of 1993

Nicole M. Kempf[1] (kempf@atmo.arizona.edu)

E. Philip Krider[1] (krider@atmo.arizona.edu)

[1]Institute of Atmospheric Physics, University of Arizona, 1118 E. 4th St. Rm. 542, Tucson, AZ 85721-0081, United States

Relationships between cloud-to-ground (CG) lightning and the excess rainfall that produced the Great Flood of 1993 have been examined. *Kunkel et al.* [1994] have reported that the excess precipitation depths in the Upper Mississippi River Basin (UMRB) were 85, 70, and 51 mm, respectively, during the months of June, July, and August, 1993. In the Greater Upper Mississippi River Basin (GUMRB), these amounts were 70, 107, and 35 mm, respectively, in the same months. The excess CG flash counts in each month in each of these regions were obtained from the U. S. National Lightning Detection Network^{TM} (NLDN) by subtracting the average of counts in 1992 and 1994 from the 1993 values. The results show that in the UMRB, there were an excess of 4.0 x 10^5, 2.6 x 10^5, and 4.8 x 10^5 CG flashes, in June, July, and August, 1993, respectively, after correcting for an imperfect network detection efficiency. In the GUMRB, there were an excess of 8.7 x 10^5, 10.4 x 10^5, and 10.5 x 10^5 CG flashes, respectively, in the same months. The ratios of the precipitation volume to CG flashes in the UMRB were 1.1 x 10^5, 1.5 x 10^5, and 0.6 x 10^5 m^3 per CG flash in June, July, and August, respectively, and 1.1 x 10^5, 1.4 x 10^5, and 0.4 x 10^5 m^3 per CG flash in the GUMRB. These values are remarkably close to the 1.1 x 10^5 m^3 per CG flash estimated by *Petersen et al.* [1998] for the summer season in the mid-continental U.S.

AE11A-0064 0830h POSTER

Modulation of Mesoscale Lightning and Rainfall over Africa by the Global 5 Day Wave

Earle R. Williams[1] (617-253-2459; earlew@ll.mit.edu)

Akash C. Patel[1] (acpatel@mit.edu)

Robert Boldi[2] (bobb@ll.mit.edu)

[1]Massachusetts Institute of Technology, Parsons Laboratory MIT 48-211, Cambridge, MA 02139, United States

[2]MIT Lincoln Laboratory, 244 Wood St, Lexington, MA 02420-9108, United States

A zonal analysis of surface pressure observations has been undertaken to understand previously correlated rainfall and mesoscale lightning activity over the African continent on a five day time scale. The mesoscale lightning is recorded globally using Schumann resonance methods at a receiving station in West Greenwich, Rhode Island. The pressure analysis confirms the presence of a dominant wavenumber-1 planetary wave, with westward progression, identified earlier by Madden and Julian (1972), a global Rossby wave with characteristic period near 5 days. The observed phase relationship indicates declining pressure over Africa when the mesoscale lightning flash rate is maximum. Other evidence supports the idea that the wave is causal to the lightning and rainfall variations. If correct, this hypothesis requires a vertical component in the planetary wave motion.

AE11A-0065 0830h POSTER

Lightning and Climate: The Water Vapor Connection

Colin G Price[1] (972-3-6406029; cprice@flash.tau.ac.il)

Mustafa Asfur[1] (972-3-6408333; mustafa@flash.tau.ac.il)

[1]Tel Aviv University, Rehov Levanon Ramat Aviv, Tel Aviv 69978, Israel

The amplitude of future global warming will depend strongly on how upper tropospheric water vapor (UTWV) changes in response to greenhouse gas forcings. However, monitoring long-term changes in UTWV is very difficult, and no single method is in place, or planned, to deal with this problem. Here we present evidence showing the close link between regional/global lightning activity and UTWV variability. Continental deep convective storms that transport large amounts of water vapor into the upper troposphere dominate the variability of global UTWV, while also being the storms that produce the majority of our planet's lightning. Furthermore, integrated regional and global lightning activity can be continuously observed from a few locations on the earth's surface via the Schumann Resonances (SR), an electromagnetic phenomenon in the atmosphere produced by global lightning. We have found that on a daily basis the regional and global UTWV maxima occur one day after the lightning activity maxima. In addition we find a clear 5- and 9-day periodicity in the lightning and water vapor time series. Observations of the SR may supply a cheap, convenient method of studying the long-term variability of global UTWV, thereby helping us further understand our global climate system.

URL: http://luna.tau.ac.il/~colin/

AE11A-0066 0830h POSTER

The Distance Lightning Travels From a Thunderstorm Based on Altitude and Atmospheric Temperature

David R Vollmer[1] (937-255-3636 ext 6316; david.vollmer@afit.edu)

Gary R Huffines[1] (937-255-3636 ext 4511; gary.huffines@afit.edu)

[1]Air Force Institute of Technology, AFIT/ENP 2950 P Street BLDG 640, Wright-Patterson AFB, OH 45433-7765, United States

Aircraft have avoidance criteria for thunderstorms that are based on flight altitude, atmospheric temperature, and the type of cloud in question. The problem arises in determining the likelihood that a lightning flash will travel a certain distance from a thunderstorm and strike an aircraft flying at any given altitude. Once this determination is made, it will then be possible to give pilots a probability of being stuck by lightning at their present altitude and distance from a storm. The calculations were done using data from 1997 to present from the Lightning Detection and Ranging (LDAR) system in place at the Kennedy Space Center in Florida. Three-dimensional locations for the individual discharges associated with a lightning flash

are available from LDAR. The origin of each flash and the horizontal extent of the lightning were determined and stratified by origin location, altitude of the outer limit of the flash, and the temperatures at either end of the flash. While the results are only valid for the Melbourne, Florida region, this technique can be applied to other areas with a network such as LDAR in place. These preliminary results show promise for improving the ability to avoid lightning strikes to aircraft in flight.

AE11A-0067 0830h POSTER

The Horizontal Distance of Cloud-to-Ground Lightning

Todd M. McNamara[1] (937-396-1530; todd.mcnamara@afit.edu)

Gary Huffines[1] (255-3636 ext 4511; gary.huffines@afit.edu)

[1]AFIT/ENP, 2950 P Street BLDG 640, Wright-Patterson AFB, OH 45433-7765

Three-dimensional lightning data from the Lightning Detection and Ranging (LDAR) system at Kennedy Space Center were combined with cloud-to-ground stroke data from the National Lightning Detection Network (NLDN) from 1997 through the summer of 2001. The horizontal distance that lightning travels from a thunderstorm to the ground was examined for this time period and the characteristics of lightning were examined for the various distances and source regions of the lightning strokes. The primary characteristic was the peak current of the stroke based on the distance traveled from and altitude of the origin location, stratified by polarity of the ground stroke. This information leads to a better understanding of the mechanisms causing the variations in peak currents as well as providing additional information for forecasting safe distances from thunderstorms.

AE11A-0068 0830h POSTER

An Evaluation of the Performance Characteristics of the NLDN Using Triggered Lightning

John A. Cramer[1] (520-806-7342; jcramer@glatmos.com)

Martin J. Murphy[1] (520-806-7458; mmurphy@glatmos.com)

David Crawford[2]

Vladimir A. Rakov[2] (352-392-4242; rakov@ece.ufl.edu)

Kenneth L. Cummins[1] (520-806-7325; kcummins@glatmos.com)

[1]Global Atmospherics, Inc., 2705 E. Medina Road, Tucson, AZ 85706, United States

[2]Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611, United States

The performance characteristics of the U.S. National Lightning Detection Network (NLDN) have been evaluated in North-central Florida using the rocket-and-wire technique to trigger lightning at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding Florida. Characteristics related to stroke detection efficiency (DE), flash DE, accuracy of location, and accuracy of peak current estimates were evaluated during the summer months of 1998-2000. Triggered-lightning strokes are similar to subsequent strokes in natural lightning. Since current and electromagnetic field waveforms are different for first and subsequent strokes, the results of this study may only be applicable to subsequent strokes.

The model-based estimate of flash DE in the test area is 80-85 percent for flashes with first-stroke peak currents greater than 5 kA, assuming that all sensors are fully operational. The expected stroke DE for natural lightning was in the range of 40-50 percent. The measured three-year average stroke DE for all rocket-triggered strokes was 25 percent, including those with peak currents below 5 kA. Strokes with peak currents below 10 kA were seldom detected. We will discuss possible mechanisms for this low stroke DE for rocket-triggered lightning. The measured three-year flash DE for all events was 70 percent. One factor that could produce a flash DE that is lower than modeled values is the lack of naturally-occurring first strokes that are thought to be statistically larger than subsequent strokes.

The median location error, employing the location algorithm employed since late 1999, varied between 500 and 600 meters over the three years. The model-based median location error for these same events ranges between 500 and 800 meters. Regarding peak current estimates, there was significant year-to-year variability in the degree of correlation between the NLDN peak current estimates and the values measured at the ICLRT. Possible sources of error in the measured and estimated peak current will be discussed.

AE11A-0069 0830h POSTER

Lightning Location With Single-Station Observation of VLF Spherics

Isamu Nagano[1] (81-76-234-4857; nagano@is.t.kanazawa-u.ac.jp)

Satoshi Yagitani[1] (81-76-234-4858; yagitani@is.t.kanazawa-u.ac.jp)

Hisao Komonmae[1] (81-76-234-4858; komonmae@reg.ec.t.kanazawa-u.ac.jp)

Naofumi Takezono[1] (81-76-234-4858; takezono@reg.ec.t.kanazawa-u.ac.jp)

[1]Department of Information and Systems Engineering, Kanazawa University, 2-40-20 Kodatsuno, Kanazawa 920-8667, Japan

Most of the lightning location systems recently available require the simultaneous reception of lightning-generated radio pulses (spherics) at multiple stations. In this work, we develop a lightning location system to determine both the direction and range of a lightning stroke with a single-station observation of VLF spherics. The technique used here is a rather classical one, but we try to improve the ranging accuracy by applying sophisticated signal processing techniques, and our final goal is to develop a portable lightning locator.

We observe wave forms of two horizontal magnetic fields and one vertical electric field of VLF spherics, each of which usually consists of a couple of sequential pulses. The first pulse comes directly from a lightning return stroke, and is used for the direction finding of the stroke. On the other hand, the second and later pulses are the multiple reflections of the first pulse inside the Earth-ionosphere waveguide. Since the time-of-arrival (ToA) of each pulse is determined by its propagation path length in the waveguide, by using the observed difference in ToA of two or more pulses, we can inversely estimate not only the reflection height at the ionosphere but also the range of the lightning stroke.

By installing the developed system at Kanazawa University, we have been observing lightning-generated spherics since April, 2000. Compared with the lightning location data provided by a local power company, preliminary analysis shows that this system can locate each lightning stroke within several hundred km with a sufficient accuracy.

AE11A-0070 0830h POSTER

Preliminary Design of a Lightning Optical Camera And ThundEr (LOCATE) sensor

Dieudonne D Phanord[1] (262-472-5684; phanordd@mail.uww.edu)

William J Koshak[2] (256-9617963; william.koshak@msfc.nasa.gov)

Paul M Rybski[1] (262-472-5766; rybskip@uww.edu)

[1]University of Wisconsin-Whitewater, 800 West Main Street, Whitewater, WI 53190, United States

[2]NASA-Marshall Space Flight Center, 320 Sparkman Drive, Huntsville, AL 35805, United States

The preliminary design of an optical/acoustical instrument is described for making highly accurate real-time determinations of the location of cloud-to-ground (CG) lightning. The instrument, named the Lightning Optical Camera And ThundEr (LOCATE) sensor, will also image the clear and cloud-obscured lightning channel produced from CGs and cloud flashes, and will record the transient optical waveforms produced from these discharges. The LOCATE sensor will consist of a full (360 degree) field-of-view optical camera for obtaining CG channel image and azimuth, a sensitive thunder microphone for obtaining CG range, and a fast photodiode system for time-resolving the lightning optical waveform. The optical waveform data will be used to discriminate CGs from cloud flashes. Together, the optical azimuth and thunder range is used to locate CGs and it is anticipated that a network of LOCATE sensors would determine CG source location to well within 100 meters. All of this would be accomplished for a relatively inexpensive cost compared to present RF lightning location technologies, but of course the range detection is limited and will be quantified in the future. The LOCATE sensor technology would have practical applications for electric power utility companies, government (e.g. NASA Kennedy Space Center lightning safety and warning), golf resort lightning safety, telecommunications, and other industries.

AE11A-0071 0830h POSTER

A Portable Data Collection Platform for Lightning Measurements

Nathan G Parker[1] (520-621-8829; parker@atmo.arizona.edu)

E Philip Krider[1] (520-621-6836; krider@atmo.arizona.edu)

[1]The University of Arizona, Institute of Atmospheric Physics, Physics-Atmospheric Sciences Bldg, Rm 542, 1118 E 4th St, PO Box 210081, Tucson, AZ 85721-0081, United States

A portable data-acquisition system has been developed from off-the-shelf digital components to provide the capability of making optical and electrical measurements of lightning in conjunction with digital video imagery. A Dolch portable PC has been integrated with a 4-channel A/D card, a GPS time/position receiver, and a Canon GL1 digital video camera. Radiometric measurements of the light output are obtained from a calibrated photo diode, and both fast and slow electric field waveforms are digitized with 14-bit resolution at up to 2.5 MHz sampling rates. Video images are recorded both on tape in the digital camera system and, if desired, can be streamed in real-time to the PC via an IEEE 1394 serial bus ("FireWire®") at 30 fps, 720x480 pixels per frame. All data streams are "pre-sampled" to capture features both before and after a trigger event, and are time-stamped with microsecond resolution using the GPS receiver.

In post processing, the video frames can be de-interlaced to double the time-resolution (to 17 ms) and the fields can be digitally enhanced to suppress any background light, thereby revealing any faint channel structures. Current applications of this system include: 1) developing a ground-truth data set for validating the performance of the LIS sensor, 2) validating the detection efficiency of the U.S. National Lightning Detection Network™, 3) quantifying the statistics of channel development and multiple ground contacts, and 4) performing basic research on branching processes and the luminous development of lightning. Examples of lightning data that have been collected for these applications will be presented.

AE11A-0072 0830h POSTER

Calibration of an Airborne Field Mill Array

Douglas M Mach[1] (256-961-7830; douglas.mach@msfc.nasa.gov)

William Koshak[2] (256-961-7963; william.koshak@msfc.nasa.gov)

Monte Bateman[3] (256-961-7804; monte.bateman@msfc.nasa.gov)

Hugh Christian[2] (256-961-7828; hugh.christian@msfc.nasa.gov)

[1]University of Alabama in Huntsville, ESSC/NSSTC, 320 Sparkman Dr., Room 4001, Huntsville, AL 35805, United States

[2]NASA/MSFC/NSSTC, 320 Sparkman Dr., Huntsville, AL 35805, United States

[3]USRA/NSSTC, 320 Sparkman Dr., Huntsville, AL 35805, United States

We measured the vector electric field in and around targets of interest near the Kennedy Space Center, Florida using a set of six rotating vane electric field mills mounted on a University of North Dakota Citation II aircraft. Each mill on the aircraft responds to the ambient vector field, (E_X, E_Y, E_Z), and the field, E_Q, due to charge on the aircraft. Our goal is to determine the "full field" $\mathbf{E} = (E_X, E_Y, E_Z, E_Q)$ from the column vector of mill outputs $\mathbf{m} = (m_1, m_2, m_3, m_4, m_5, m_6)$. In matrix form, the linear retrieval for the full field can be written $\mathbf{E} = \mathrm{C}\mathbf{m}$, where C is a (4x6) calibration matrix. To determine C, we first estimate its inverse M, where M is a (6x4) matrix (and where $\mathbf{m} = \mathrm{M}\mathbf{E}$) based on aircraft shape and symmetry arguments. We then use the Moore-Penrose pseudoinverse to estimate C. If the initial estimates of the mill responses M are close, the resultant electric field component estimates will be dominated by the proper component with "contaminations" from the other three (for example, $E_{Xest} = E_{Xtrue} + \epsilon_1 * E_{Ytrue} + \epsilon_2 * E_{Ztrue} + \epsilon_3 * E_{Qtrue}$ where ϵ_1, ϵ_2, and ϵ_3 are small). We use this information to correct the calibration matrix. We then use the Moore-Penrose pseudoinverse again to create a better mill response matrix, M. We correct M for any known symmetries in the electric field responses of the mills and continue the iterative process. Once the iterative process has been completed, the final C matrix can then be used to determine $\mathbf{E}$ for all cases. We also compare our results to an independent method developed by one of the authors (Koshak). Although the two methods involve very different approaches, they achieve similar results. One advantage of our method using the Moore-Penrose pseudoinverse is that it is simple to emphasize or de-emphasize mills when we calculate the calibration matrix.

AE11A-0073 0830h POSTER

Long-term Observations of Electric Field, Temperature, Pressure, Humidity, Wind Speed, Wind Direction, Rainfall Rate and Solar Insolation at a Remote Meteorological Observing Station

Frank W. Gallagher[1] (405-325-6561; fgallagher@ou.edu)

William H. Beasley[1] (405-325-3440; wbeasley@ou.edu)

Aaron R. Bansemer[2] (303-497-8913; abansemer@ucar.edu)

David L. Grimsley[3] (dgrimsley@ou.edu)

Leon G. Byerley[4] (520-326-1129; byerley@theriver.com)

[1]School of Meteorology, University of Oklahoma, Norman, OK 73019, United States

[2]NCAR/MMM Division, 3450 Mitchell Lane, Bldg. 3, Boulder, CO 80301, United States

[3]Oklahoma Climatological Survey, University of Oklahoma, Norman, OK 73019, United States

[4]Lightning Protection Technology, East 5th St., Tucson, AZ, United States

For nearly two years we observed the electric field at the surface continually and simultaneously with observations of temperature, pressure, humidity, wind speed and direction, rainfall rate and solar insolation at a remote automated meteorological observing station in Norman, OK. The electric-field observations were made with electric-field mills that were cycled on every few minutes for a period of about 20 seconds, 24 hours a day, seven days a week for the entire period of time. We observed a number of interesting patterns in the observations, some familiar and some not. For example, monthly averages of the observations often yield Carnegie curves, but not always. We noted what appears to be a sunrise effect on some days. We present a representative sample of the observations.

AE11A-0074 0830h POSTER

Simulations of Spatial and Temporal Variations of Electric Field at the Surface Beneath Thunderstorms

Aaron R. Bansemer[1] (303-497-8913; abansemer@ucar.edu)

William H. Beasley[2] (405-325-3440; wbeasley@ou.edu)

Frank W. Gallagher[2] (405-325-6561; fgallagher@ou.edu)

Leon G. Byerley[3] (520-326-1129; byerley@theriver.com)

[1]NCAR/MMM Division, 3450 Mitchell Lane, Bldg. 3, Boulder, CO 80301, United States

[2]School of Meteorology, University of Oklahoma, Norman, OK 73019

[3]Lightning Protection Technology, E. 5th St., Tucson, AZ, United States

In order to begin to understand how to deal with data streams from large networks of closely spaced electric-field meters, we have simulated the growth and decay of electrified storms over such a network, and consequently, the spatial and temporal variations of contours of electric field at the surface. We assumed realistic locations and spacing for approximately 50 sensors based on an existing network of remote meteorological observing stations. We assumed simple thunderstorm charge distributions with linear growth and decay of the amounts of charge. We simulated stationary charge distributions overhead, distributions that moved horizontally as if advected by a mean wind, and vertically oriented as well as tilted charge distributions. We also included the effects of CG and IC lightning discharges. We calculated the electric field at the sensor locations and then interpolated contours of constant value of the field for each time step. We present some representative simulations that suggest directions for future research.

AE12A MC: Hall D Monday 1330h

Lightning and Storm Electrification II

Presiding: **P Krider,** Atmospheric Physics, University of Arizona**; R Orville,** Dept. of Atmos. Sci., Texas AM University

AE12A-0075 1330h POSTER

VHF Global Lightning and Severe Storm Monitoring From Space: Storm-level characterization of VHF lightning emissions

David M Suszcynsky[1] (505-665-3119; dsuszcynsky@lanl.gov)

Sean M Davis[1] (505-667-8784; sdavis@lanl.gov)

Abram R Jacobson[1] (505-667-9656; ajacobson@lanl.gov)

Matt J Heavner[1] (505-66; mheavner@lanl.gov)

Morris B Pongratz[1] (505-667-4740; mpongratz@lanl.gov)

[1]Los Alamos National Laboratory, Space and Atmospheric Sciences Group MS D466, Los Alamos, NM 87545, United States

Over the last few decades, there has been a growing interest to develop and deploy an automated and continuously operating satellite-based global lightning monitor. The resulting unprecedented data set would be applicable to the commercial and military aviation communities, and to the regional/global meteorology and climatology communities. To date, efforts to develop such a system have focussed on the deployment of optical sensors which can provide cost-effective single-platform geolocation of lightning events. Recently, we have presented a proposal to develop a GPS satellite-based global lightning and severe storm monitor based on the detection of VHF emissions from lightning. This presentation concentrates on characterizing the storm-level climatology of the VHF lightning emissions that would be detected by such a monitor. Analysis of existing data sets such as those from the Fast On-Orbit Recording of Transient Events (FORTE) satellite are used to show that a GPS-based VHF lightning monitor would primarily detect narrow ($\sim 1\mu s$) impulsive signatures that are associated with narrow bipolar events (NBEs). These signatures are ubiquitous and are commonly associated with strong convective activity.

AE12A-0076 1330h POSTER

Determination of Ice Precipitation Rates and Thunderstorm Anvil Ice Contents from Satellite Observations of Lightning

Alan M. Blyth[1] (blyth@env.leeds.ac.uk)

Hugh J. Christian[2] (christian@msfc.nasa.gov)

Kevin Driscoll[2] (driscoll@msfc.nasa.gov)

John Latham[3] (303-497-8992; latham@ucar.edu)

[1]School of Environment, University of Leeds, Leeds, United Kingdom

[2]GHCC, 977 Explorer Blvd., Huntsville, AL 35806, United States

[3]NCAR/MMM, 3450 Mitchell Lane, Boulder, CO 80301, United States

Simple calculations and modelling predict that the lightning frequency f is proportional to the product of the downward flux of solid precipitation through the body of the thundercloud and the upward flux of ice crystals into its anvil.

Calculations indicate that the separation of charge and associated field development in thunderclouds are not significantly limited by charge saturation of the interacting hydrometeors: and that the mutual interactions of graupel pellets in the charging zones of thunderstorms can significantly enhance electric field development, culminating in lightning.

An examination of data from the satellite-borne Lightning Imaging Sensor and TRMM Microwave Imager indicates that thunderstorms with the highest frequency of total lightning also possess the most pronounced microwave scattering signatures at 37 and 85 GHz. These findings are consistent throughout the seasons in a variety of regimes (12 sites encompassing 5 continents, as well as oceanic measurements), suggesting that global relationships may exist between lightning activity and cloud ice contents and/or fluxes.

AE12A-0077 1330h POSTER

A Model Study of Anvil-top Plume Formation in the 20 July 2000 Denver Thunderstorm

Pao K Wang[1] (608-263-6479; pao@windy.meteor.wisc.edu)

Hsin M Lin[1] (608-262-0794; moon@wangsgi.meteor.wisc.edu)

Walter A Lyons[2] (970-568-7664; walyons@mail.frii.com)

[1]Department of Atmospheric and Oceanic Sciences, University of Wisocnsin-Madison 1225 W. Dayton Street, Madison, WI 53706, United States

[2]FMA Research, Inc, Yucca Ridge Field Station 46050 Weld County Road 13, Fort Collins, CO 80524, United States

A supercell convective storm northeast of Denver, Colorado on 20 July 2000 was observed by team members of STEP2000 project to have a trailing cirrus plume formation above the anvil. Since the formation of plumes above thunderstorm anvils may represent a transport of water vapor (and possibly other chemical species) from the troposphere to the stratosphere, the mechanism responsible for this phenomenon deserves a detailed examination. In this paper, we will report a numerical model simulation study utilizing a 3-D non-hydrostatic, quasi-compressible cloud model with detailed cloud microphysics to simulate the evolution of this storm. We will perform analyses of the dynamic and microphysical structures of the simulated storm to identify the mechanism responsible for the plume formation above the anvil. Preliminary results indicate that the breaking of gravity waves at and above the anvil level is a strong candidate mechanism for this phenomenon. The shell of the overshooting dome seems to be the main source of water vapor for the plume, especially in the mature stages of the storm. The details of the results will be presented at the time of the conference.

AE12A-0078 1330h POSTER

Observations of Hydrometeor Electric Charge in Thunderstorms

Andrew Detwiler[1] (605-394-2291; Andrew.Detwiler@sdsmt.edu)

John Helsdon[1] (605-394-2291; John.Helsdon@sdsmt.edu)

Donna Kliche[1] (605-394-2291; Donna.Kliche@sdsmt.edu)

Qixu Mo[1] (65-394-2291; Qixu.Mo@sdsmt.edu)

William Winn[2] (505-835-5503; winn@loon.nmt.edu)

[1]Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid Ctiy, SD 57701, United States

[2]Langmuir Laboratory, New Mexico Institute of Mining and Technology, Socorro, NM 87801, United States

Despite general acceptance of the hypothesis that charge separation in thunderstorms is largely due the non-inductive ice-ice collision charging mechanism, it has been difficult to interpret observations of hydrometeor charges in storms in terms of this hypothesis. In particular, most observations of hydrometeor charge show no clear trend for larger charges to be found on larger particles, which presumably have undergone more collisions. It quite often is observed that the largest charges are found on smaller particles. Interpretation of the observations is made difficult by chaotic hydrometeor trajectories in typical thunderstorms, the presence of lightning, and other complicating factors. During the Severe Thunderstorm Electrification and Precipitation Study (STEPS), in the summer of 2000, observations of several storms were obtained using multiple Doppler and dual-polarization meteorological radars, a lightning-leader mapping array, the National Lightning Detection Network (NLDN) cloud-to-ground lightning mapper, instrumented balloons and aircraft, and a mobile mesonet. A special instrument on the aircraft provided hydrometeor shadow imagery and charge observations. Using the coordinated observations, it is possible to isolate regions along the aircraft storm penetration tracks where the developmental history of the particles observed can be inferred with some certainty. These regions include updraft, updraft/downdraft transition, downdraft, trailing stratiform, and below-cloud base precipitation shafts. Comparisons of the observed hydrometeor charge distributions are made to those expected from collision charging. In some regions, observations conform to expected distributions, and in other regions, interpretation is less clear.